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Specifications

1. Title of the Invention:

Apparatus for Control of the Feed Rate of Water Purification Plant Reagent

2. Limits of the Patent Claims

(Claim 1) An apparatus for the control of the feed rate of reagent at a water purification plant, characterized in that the apparatus obtains stable water quality and that the apparatus consists of

a source water quality measurement device for measurement of the water quality of the source water intake of the water purification plant;

a reagent feed device for feeding reagent to the source water;

a ratio setting device that maintains a ratio of the reagent feed rate to the source water intake rate;

a settling water quality measurement device that measures the water quality of settling water and that outputs a signal; and

a calculating control device that receives said output signal from said settling water quality measurement device, that receives an output signal from said source water quality measurement device, that sets the flow rate of said reagent, and that sets said ratio setting device.

3. Detailed Explanation of the Invention

This invention pertains to an apparatus for control of the feed of reagent to a water purification plant so that this feed is carried out in a stable and efficient manner. The apparatus of this invention carries out such control by raising and lowering the feed rate of a reagent that is used for the adjustment of water quality.

At a prior art water purification plant, water treatment reagents are fed into the source water. Such reagents have typically included caustic soda, flocculants, etc. Examples of such flocculants include aluminum sulfate, polyaluminum chloride, etc. The degree of flocculation is maintained constant, and problems are prevented that would have resulted from long-term variations in the source water turbidity. Such prior art water treatment utilizes an analog controller for the feed of this treatment reagent. An operator sets the ratio of the reagent feed rate to the source water intake rate. Typically control is carried out at using a fixed set point for this reagent feed ratio.

The reagent feed ratio is determined by the personal experience of the operator or by the results of batch-wise test samples. The skill of the operator determines the reagent consumption rate when the reagent feed ratio is set according to operator experience, resulting in variation of the results of flocculation. Furthermore, although it is possible to effectively control the feed of reagent when batch-wise test results are utilized, a time period is required to respond to changes in the source water. Batch-wise testing is deficient in that source water quality variations can not be tracked.

In addition to the above-described methods, it is possible to create a reagent feed ratio model (or correlation equation) based upon water purification plant historical data for source water quality and the reagent feed ratio. However, this method requires considerable historical data, and a great deal of time and effort are needed to formulate the model. This method is also deficient in that, as long term variations in the effectiveness of flocculation occur due to source water turbidity, it is impossible to react to such changes due the great effort needed to determine model parameters.

Per this invention, variations in the source water quality are automatically tracked so as to minimize the quantity of reagent that is consumed. The goal of this invention is to provide a water purification plant reagent feed rate control apparatus that can carry out stable and efficient reagent feed while reducing the effects of long term variations in source water turbidity.

The invention is explained below while referring to illustrations. Item 10 within **Figure 1** is a calculating control device. Item 11 is an inlet water well. Item 12 is a reagent flash mixing reservoir. Item 13 is a settling reservoir. Item 14 is a filtration reservoir. Item 21 is a settling reservoir intake flow meter. Item 22 is a settling reservoir intake flow control valve. Item 31 is a flocculant feed rate meter that is used for measuring the rate of feed of aluminum sulfate or polyaluminum chloride, etc. Item 32 is a flocculant feed control valve. Similarly, items 41 and 42 are respectively a caustic soda, etc. alkaline reagent feed rate meter and an alkaline reagent feed control valve. Items 51, 52, 53, and 54 are meters used for measuring quality of the source water. These measure respectively the turbidity, alkalinity, pH, and temperature. The measured signals are transmitted over respective signal lines 71, 72, 73, and 74 to calculating control device 10. Items 61 and 62 are water quality meters that measure the water quality of the settling reservoir water. These measure respectively the turbidity and the pH. The respective measurement signals are transmitted via signal lines 81, 82 to calculating control device 10.

Calculating control device 10 transmits a flocculant feed ratio signal that is used as input by a ratio setting device 35 that outputs a signal to a ratio setting multiplier 36. Ratio setting multiplier 36 receives both a flocculant feed ratio value signal from ratio setting device 35 and, via signal line 91, a flocculant reservoir intake flow signal from flocculant reservoir intake flow meter 21. The ratio setting multiplier 36 carries out multiplication to determine the flocculant feed rate setting that is output to flow controller 37. Flocculant flow control is carried out by flocculant

flow controller 37 as flocculant flow controller 37 receives a flocculant flow control setting from ratio setting multiplier 37 and a flow rate value from flocculant feed rate meter 31. This flow controller carries out control calculations and then opens / closes flocculant feed control value 32. For the alkaline reagent and in the same manner, items 45, 46, and 47 are the respective ratio setting device, ratio setting multiplier, and flow controller.

By the use of the above-described equipment for both flocculation (within settling reservoir 13 by use of a flocculant such as aluminum sulfate, polyaluminum chloride, etc.) and filtration (within filtration reservoir 14), the above-described equipment determines water quality according to the source water quality, the feed ratio of flocculant to reagent flash mixing reservoir 12, and the settling reservoir water pH. Per this invention, the relationship between the source water quality and the most appropriate flocculant feed ratio is stored in memory by calculating control device 10. The most appropriate flocculant feed ratio is determined based upon the source water quality at a given time, and the flocculant feed ratio setting is output to ratio setting device 35. Simultaneously the source water quality and the flocculant feed ratio are considered, and settling reservoir water pH is adjusted to the most appropriate value by utilizing the alkaline reagent and the (acidic) flocculant.

The results of the reagent feed are determined in terms of the water quality of the settling reservoir water so that an optimum relationship is always maintained between the source water quality and the flocculant feed ratio.

Among the various water quality parameters of the source water, source water turbidity most greatly affects flocculant feed to reagent flash mixing reservoir 12. Compensations are made for the source water alkalinity, pH, and temperature. The relationship between the source water turbidity T and the optimum flocculant feed ratio R_B varies according to flocculant, etc. used for with source water. Although this relationship can be determined based upon an analysis of historical data, the optimum flocculant feed ratio R_B is generally determined by a source water turbidity T curve such as that shown in **Figure 2**.

Figure 2 shows the relationship between the source water turbidity T and the optimum flocculant feed ratio R_B. Here the settling reservoir water residual turbidity setting is T_0. The optimum flocculant feed ratio R_{B0} is then determined from the source water turbidity T_1. A flocculant feed ratio correction OR_{B0} is determined using corrections for the source water alkalinity (ALK), pH (PH), and temperature (Temp), so the actual utilized flocculant feed ratio R_{BT} is given by the following equation. [*TRANSLATOR'S NOTE:* OR_{B0} *seems to be a typo. This clearly should have been* ΔR_{B0}.]

$$R_{BT} = R_{B0} + \Delta R_{B0} \quad \ldots \quad (1)$$

If the alkaline reagent (or flocculant) feed ratio R_{A1} (or R_{B1}) is selected in order that the settling reservoir water pH reaches an optimum value, the flocculant feed ratio R_{BT} and the alkaline reagent feed ratio R_{AT} can be determined from the following equations:

$$\left.\begin{aligned} R_{BT} &= R_{B0} + \Delta R_{B0} \\ R_{AT} &= R_{A1} \end{aligned}\right\} \quad \ldots \quad (2)$$

$$\left.\begin{aligned} R_{BT} &= R_{B0} + \Delta R_{B0} + \Delta B1 \\ R_{AT} &= 0 \end{aligned}\right\} \quad \ldots \quad (3)$$

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[*TRANSLATOR'S NOTE: The (2) equations refer to the case where pH control is carried out by use of only the alkaline reagent. The (3) equations refer to the case where pH control is carried out by use of the flocculant alone. Mention of* $\Delta B1$ *in the (3) equations is clearly a typo. This should have been* ΔR_{B1}.]

The calculation method is stored in the memory of the calculating control device 10 for calculation of the flocculant feed ratio and the alkaline reagent feed ratio. These calculated values of R_{BT} and R_{AT} are sent to the respective ratio setting devices 35 and 45.

The settling reservoir water residual turbidity T'_0 is measured after a treatment time interval t has passed. This time interval t is defined as the time period required for treated water to reach the outlet of settling reservoir 13 after feed of reagent to reagent flash mixing reservoir 12. While time interval t is used as an input by calculating controller device 10, calculating controller device 10 determines the difference between the residual turbidity setting T_0 and the actual residual turbidity. This turbidity difference exceeds a permissible range when the optimum flocculant feed ratio curve indicates an optimum flocculant feed relationship that is not actually the optimum relationship. The calculating controller device 10 then corrects the optimum flocculant feed ratio curve.

The calculating control device 10 is not able to simply correct the optimum flocculant feed ratio curve by a simple parallel displacement of the curve. If the needed correction is considered for a single value for the source water turbidity, it is realized that correction must be made to the optimum flocculant feed ratio curve centered on this source water turbidity. Therefore, as shown in **Figure 3**, the peak value at this source turbidity T_1 must be considered, and then the flocculant feed ratio curve is corrected upward or downward while taking this displacement into account. The maximum value of this correction curve is the differential function (between the settling reservoir water measured residual turbidity T'_0 and the settling reservoir water residual turbidity setting T_0) which is defined as $K_1(T'_0 - T_0)$. This correction curve is combined with the optimum flocculant feed ratio curve C_1, as shown in **Figure 4**, resulting in a new optimum flocculant feed ratio curve C_2.

When the equation below is used as an example of an optimum feed ratio curve such as that shown in **Figure 2**, as per the above equations, the resultant correction curve example is shown in **Figure 3**.

$$R_B = A \cdot 10(BT + CT^2 + DT^3) \ \ldots \qquad (4)$$

[*TRANSLATOR'S NOTE: Another typo. Equation (6) makes it clear that equation (4) should show 10 to the polynomial power.*] This **Figure 3** example correction curve is indicated by the following equation:

$$R'_B = [K_1(T'_0 - T_0)] / [(T - T_1)^2 + 1]$$

[*TRANSLATOR'S NOTE: The above equation was not labeled, although it is clearly no. 5.*] **Figure 4** shows the corrected optimum feed ratio curve which is given below:

$$R_B = R_B + R'_B = A \cdot 10^{(BT + CT^2 + DT^3)} + [K_1(T'_0 - T_0)] / [(T - T_1)^2 + 1] \ \ldots \ (6)$$

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Even if the feed ratio equation that is used differs from that of the above example, for a feed ratio curve that has similar curvature, it is generally possible to use this method for the relationship between the source water turbidity and the optimum flocculant feed ratio.

Per this invention, the difference is determined between the measured settling reservoir water residual turbidity T'_0 input and the settling reservoir water residual turbidity setting T_0. If this differential is within a permissible range, the correction curve is found for source water turbidity T_1 at a time interval *t* earlier, where *t* is the time period required for treated water to reach the outlet of the settling reservoir after feed of reagent. Then this correction curve is used to adjust the optimum flocculant feed ratio curve. This process is repeated at time intervals equal to this treatment time interval *t*. Therefore per this invention, the relationship is revised between the source water quality and the optimum flocculant feed ratio, despite any long-term variations in the source water flocculation properties, etc. The water quality of the settling water is maintained constant, and the reagent feed rate is kept to a minimum. It is possible to feed reagent with efficiency and stability.

Also per this invention, in comparison to the prior art method that required the analysis of a great deal of data in order to construct a reagent feed ratio model, the feed ratio relationship is automatically corrected step-wise to give an optimum relationship based upon actual data. It becomes possible to perform reagent feed rate control without the considerable time and effort required by the prior art method.

Furthermore, the above-described working example uses a SCC type method for each reagent by outputting a feed ratio setting to a ratio setting device that then multiples the settling reservoir intake flow rate times the feed ratio setting, followed by this reagent feed rate setting value being output to a flow controller, thereby controlling the reagent feed. However, it is also possible for such calculations to be carried out within the calculating control device 10 itself rather than in a ratio setting device, a multiplier, and a flow controller. This alternative would make possible ready DDC type direct control of the feed control valve.

4. Simple Explanation of the Illustrations

The illustrations show a working example of this invention. **Figure 1** is a block diagram that shows the content of this invention. **Figure 2** is a diagram that shows the relationship between source water turbidity and the optimum flocculant feed ratio. **Figure 3** is a diagram that shows a curve used for correcting the relationship of **Figure 2**.

10 ... Calculating Control Device
11 ... Inlet Water Well
12 ... Reagent Flash Mixing Reservoir
13 ... Settling Reservoir
14 ... Filtration Reservoir
21 ... Settling Reservoir Intake Flow Meter
22 ... Settling Reservoir Intake Flow Control Valve
31 ... Flocculant Feed Rate Meter
32 ... Flocculant Feed Control Valve
35 ... Flocculant Ratio Setting Device
36 ... Ratio Setting Multiplier
37 ... Flow Controller

41 ... Alkaline Reagent Feed Rate Meter
42 ... Alkaline Reagent Feed Control Valve
45 ... Alkaline Reagent Ratio Setting Multiplier
46 ... Ratio Setting Multiplier
47 ... Flow Controller
51 ... Source Water Turbidity Meter
52 ... Source Water Alkalinity Meter
53 ... Source Water pH Meter
54 ... Source Water Temperature Meter
61 ... Settling Reservoir Water Turbidity Measurement Device
62 ... pH Measurement Device
71, 72, 73, 74, 81, 82, 91 ... Signal Lines

Figure 1

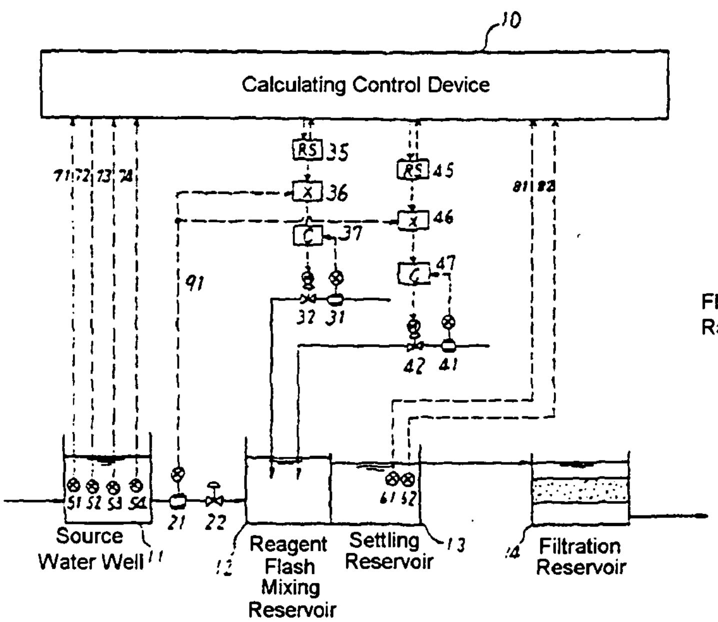

Figure 2

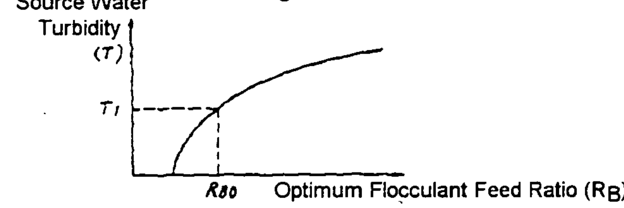

Figure 3

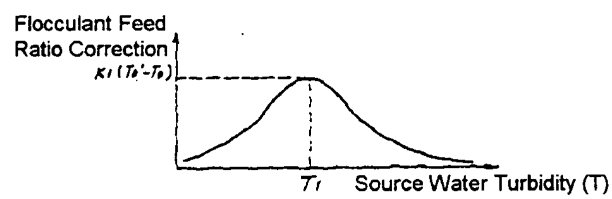

Figure 4